

## CLAIMS

What is claimed is:

- 1 1. A user interface device to manipulate a position of a cursor  
2 on a screen display in an electronic apparatus, comprising:  
3 a tracking element actuatable to track the position of said  
4 cursor on said screen display;  
5 at least one motor interconnected to said tracking element and  
6 having a position encoder connected thereto, each said position  
7 encoder generating a motor position signal indicative of the  
8 position of a respective motor;  
9 a controller receiving cursor position information from said  
10 electronic apparatus and motor position information from a  
11 respective encoder;  
12 a store of force-position information accessible to said  
13 controller, said controller accessing said store of force-position  
14 information in response to at least one of said cursor position  
15 information and said motor position signal to generate, using said  
16 at least one motor, a positive or negative force in said tracking  
17 element as a function of a position of said cursor on said screen  
18 display.
- 19 2. The user interface device of claim 1 wherein said tracking  
20 element is a sphere interfaced to said at least one motor by at  
21 least two sets of wheels contacting said sphere and said at least  
22 two sets of wheels are aligned on mutually orthogonal axes.

23 3. The user interface device of claim 2 wherein each of said at  
24 least two sets of wheels comprises a hub about which a pair of  
25 frames is disposed and each of said pair of frames includes  
26 gripping members staggered in a manner so that there is always a  
27 gripping member in contact with said sphere.

28 4. The user interface device of claim 1 wherein said at least one  
29 motor comprises a plurality of motors and each of said plurality of  
30 motors has an associated complementary motor connected in series.

31 5. The user interface device of claim 1 wherein said at least one  
32 motor comprises a plurality of motors and each of said plurality of  
33 motors has an associated complementary bearing.

34 6. The user interface device of claim 1 wherein said at least one  
35 motor comprises a plurality of motors each interconnected to said  
36 tracking element by at least one set of wheels aligned on mutually  
37 orthogonal axes and configured to sense or impart motion of the  
38 tracking element on a respective axis.

39 7. The user interface device of claim 6 wherein said plurality of  
40 motors each interconnected to said tracking element by at least one  
41 set of wheels aligned on mutually orthogonal axes are configured to  
42 sense or impart motion of the tracking element on mutually  
43 orthogonally disposed x and y-axes.

44 8. The user interface device of claim 7 further including at  
45 least one set of wheels configured to sense or impart motion of the  
46 tracking element on a z-axis orthogonally disposed with respect to  
47 said x and y-axes.

48 9. A method of generating tactile responsiveness in a user  
49 interface device having a tracking element manipulating a position  
50 of a displayed element on a display screen of an electronic device,  
51 said method comprising the steps of:

52 positioning a plurality of drive/position assemblies along  
53 mutually orthogonal axes with respect to said tracking element,  
54 each of said plurality of drive/position assemblies including a  
55 motor and an associated encoder to drive and sense position of said  
56 tracking element;

57 interfacing said user interface device to said display screen  
58 via a controller that receives information from said associated  
59 encoder of each of said plurality of drive/position assemblies and  
60 from said electronic device to track movement of said tracking  
61 element and the position on said display screen of said displayed  
62 element;

63 storing force-position relation information, accessible to  
64 said controller, as a function of the position on the display  
65 screen of the displayed element; and

66 accessing said force-position information via said controller  
67 and generating a signal to each of said plurality of drive/position  
68 assemblies to effect a positive or negative force to respectively

69 assist or resist motion of said tracking element depending upon the  
70 position of said displayed element on said display screen.

71 10. The method of claim 9 wherein said step of positioning a  
72 plurality of drive/position assemblies further includes positioning  
73 a corresponding plurality of complementary slave assemblies along  
74 corresponding mutually orthogonal axes, each of said complementary  
75 slave assemblies being electrically connected in series with a  
76 respective one of said plurality of drive/position assemblies.

77 11. The method of claim 9 wherein the step of interfacing said  
78 user interface device to said display screen via said controller  
79 includes interconnecting said electronic device to said controller  
80 to send and receive information about the position of the displayed  
81 element on said display screen between said electronic device and  
82 said controller, and interconnecting said plurality of  
83 drive/position assemblies to said controller to send said signal to  
84 each of said plurality of drive/position assemblies to effect said  
85 positive or negative force to respectively assist or resist motion  
86 of said tracking element depending upon the position of said  
87 displayed element on said display screen.

88 12. A user interface device having tactile feedback capabilities,  
89 comprising:

90 an actuatable member for imparting a tactile feedback to a  
91 user of said user interface device;

92 a motor interconnected to said actuatable member;  
93 a position encoder in communication with said motor, said  
94 position encoder providing position information of said motor;  
95 a controller receiving said position information from at least  
96 said position encoder;  
97 a store of force-position relation information accessible to  
98 said controller, said controller outputting at least one force  
99 value corresponding to said position information in accordance with  
100 said store of force-position relation information; and  
101 a drive signal source generating a drive signal to said motor  
102 in accordance with said at least one force value, said drive signal  
103 causing a force in said motor to provide said tactile feedback to  
104 said actuatable member to assist or resist motion of said  
105 actuatable member.

106 13. The user interface device of claim 12 further including a  
107 counter receiving said position information of said motor and  
108 providing a count to said controller, said controller outputting a  
109 force value corresponding to said position information in  
110 accordance with said store of force-position relation information.

111 14. The user interface device of claim 13 wherein said force value  
112 is a digital force value and further including a digital to analog  
113 converter receiving said digital force value and converting said  
114 digital force value to an analog force signal.

115 15. The user interface device of claim 14 further including a  
116 power amplifier receiving said analog force signal and generating  
117 said drive signal to said motor in accordance with said at least  
118 one force value, said drive signal being proportional to said  
119 analog force signal.

120 16. The actuator of claim 12 wherein said controller is a  
121 microprocessor receiving said position information on at least one  
122 port thereof.

123 17. The actuator of claim 16 wherein said microprocessor includes  
124 resident erasable programmable read only memory which is used for  
125 said store of force-position relation information.

126 18. The actuator of claim 12 wherein said drive signal source is  
127 a current source including a power amplifier and said drive signal  
128 is a current provided by said power amplifier.